METHOD AND APPARATUS FOR DISPLAYING A SUB-PICTURE OVER A BACKGROUND PICTURE ON A BI-STABLE DISPLAY

The invention relates generally to electronic reading devices such as electronic books and electronic newspapers and, more particularly, to a method and apparatus for displaying a sub-picture with a frame over a background picture to mask the effects of color drift in the background picture.

Recent technological advances have provided "user friendly" electronic reading devices such as e-books that open up many opportunities. For example, electrophoretic displays hold much promise. Such displays have an intrinsic memory behavior and are able to hold an image for a relatively long time without power consumption. Power is consumed only when the display needs to be refreshed or updated with new information. So, the power consumption in such displays is very low, suitable for applications for portable e-reading devices like e-books and e-newspaper. Electrophoresis refers to movement of charged particles in an applied electric field. When electrophoresis occurs in a liquid, the particles move with a velocity determined primarily by the viscous drag experienced by the particles, their charge (either permanent or induced), the dielectric properties of the liquid, and the magnitude of the applied field. An electrophoretic display is a type of bi-stable display, which is a display that substantially holds an image without consuming power after an image update.

For example, international patent application WO 99/53373, published April 9, 1999, by E Ink Corporation, Cambridge, Massachusetts, US, and entitled Full Color Reflective Display With Multichromatic Sub–Pixels, describes such a display device. WO 99/53373 discusses an electronic ink display having two substrates. One is transparent, and the other is provided with electrodes arranged in rows and columns. A display element or pixel is associated with an intersection of a row electrode and column electrode. The display element is coupled to the column electrode using a thin film transistor (TFT), the gate of which is coupled to the row electrode. This arrangement of display elements, TFT transistors, and row and column electrodes together forms an active matrix. Furthermore, the display element comprises a pixel electrode. A row driver selects a row of display elements, and a column or source driver supplies a data signal to the selected row of display elements via the column electrodes and the TFT

transistors. The data signals correspond to graphic data to be displayed, such as text or figures.

The electronic ink is provided between the pixel electrode and a common electrode on the transparent substrate. The electronic ink comprises multiple microcapsules of about 10 to 50 microns in diameter. In one approach, each microcapsule has positively charged white particles and negatively charged black particles suspended in a liquid carrier medium or fluid. When a positive voltage is applied to the pixel electrode, the white particles move to a side of the microcapsule directed to the transparent substrate and a viewer will see a white display element. At the same time, the black particles move to the pixel electrode at the opposite side of the microcapsule where they are hidden from the viewer. By applying a negative voltage to the pixel electrode, the black particles move to the common electrode at the side of the microcapsule directed to the transparent substrate and the display element appears dark to the viewer. At the same time, the white particles move to the pixel electrode at the opposite side of the microcapsule where they are hidden from the viewer. When the voltage is removed, the display device remains in the acquired state and thus exhibits a bi-stable character. In another approach, particles are provided in a dyed liquid. For example, black particles may be provided in a white liquid, or white particles may be provided in a black liquid. Or, other colored particles may be provided in different colored liquids, e.g., white particles in green liquid.

Other fluids such as air may also be used in the medium in which the charged black and white particles move around in an electric field (e.g., Bridgestone SID2003 – Symposium on Information Displays. May 18-23, 2003, - digest 20.3). Colored particles may also be used.

To form an electronic display, the electronic ink may be printed onto a sheet of plastic film that is laminated to a layer of circuitry. The circuitry forms a pattern of pixels that can then be controlled by a display driver. Since the microcapsules are suspended in a liquid carrier medium, they can be printed using existing screen-printing processes onto virtually any surface, including glass, plastic, fabric and even paper. Moreover, the use of flexible sheets allows the design of electronic reading devices that approximate the appearance of a conventional book.

In order to reduce power consumption and update time, a sub-picture may be displayed over an existing background picture by defining a partial display window or

picture rather than updating the entire display screen. The introduction of a sub-window on an entire display also enhances the feature, functionality and user convenience for reading, in particular for an electronic dictionary. The sub-picture and background picture can be a black and white (monochrome), greyscale or color picture. Although an electrophoretic display is bi-stable, the brightness of various color states will drift over time toward a middle color level. For example, an existing white background will tend to become light grey over time. If a sub-picture with a clean white background is displayed over such a background, the change in color will be noticeable. As a result, when the sub-picture with the same nominal, pre-drift grey level as the background picture is updated close to the background picture, a difference will be visible to the user, resulting in poor performance. This problem is present for both partial display updates and full image updates. When a pixel does not change color, the controller does not activate/refresh it, although we can do this by filling in data in the look-up-table (LUT). It would therefore be desirable to mask the effect of color drift in a background image when a sub-picture is displayed over a background picture.

The present invention addresses the above and other issues.

In a particular aspect of the invention, a method for displaying a sub-picture over a background picture on an electronic reading device includes determining a visual characteristic of at least a portion of the background picture, determining a visual characteristic of at least a portion of the sub-picture, determining whether a difference in the visual characteristics exceeds a minimum threshold, displaying the sub-picture over the background picture with a frame when the difference exceeds the minimum threshold, and displaying the sub-picture over the background picture without a frame when the difference does not exceeds the minimum threshold. The visual characteristics may be a color or greyscale level, for example.

A related electronic reading device and program storage device are also provided.

In the drawings:

Fig. 1 shows diagramatically a front view of an embodiment of a portion of a display screen of an electronic reading device;

Fig. 2 shows diagramatically a cross-sectional view along 2-2 in Fig. 1;

Fig. 3 shows diagramatically an overview of an electronic reading device;

Fig. 4 shows diagramatically two display screens with respective display regions;

Fig. 5 shows a clean white sub-picture with no frame displayed over a degraded white background picture;

Fig. 6 shows a clean white sub-picture with a frame displayed over a degraded white background picture;

Fig. 7 shows two clean white sub-pictures with no frame displayed over a degraded white background picture;

Fig. 8 shows a first sub-picture with a degraded white portion and a clean white portion and no frame displayed over a degraded white background picture, and a second sub-picture with a clean white portion and no frame displayed over a previous sub-picture having a degraded white portion;

Fig. 9 shows first and second sub-pictures with clean white portions and frames displayed over a degraded white background picture;

Fig. 10 shows a method for determining whether to display a frame with a sub-picture;

Fig. 11 illustrates a decay in brightness versus time;

Fig. 12 illustrates a photo-sensor situated above the top electrode on the foil side of a display; and

Fig. 13 illustrates a photo-sensor situated on or adjacent to the pixel electrode on the active plate of the display.

In all the Figures, corresponding parts are referenced by the same reference numerals.

Figures 1 and 2 show the embodiment of a portion of a display panel 1 of an electronic reading device having a first substrate 8, a second opposed substrate 9 and a plurality of picture elements 2. The picture elements 2 may be arranged along substantially straight lines in a two-dimensional structure. The picture elements 2 are shown spaced apart from one another for clarity, but in practice, the picture elements 2 are very close to one another so as to form a continuous image. Moreover, only a portion of a full display screen is shown. Other arrangements of the picture elements are possible, such as a honeycomb arrangement. An electrophoretic medium 5 having charged particles 6 is present between the substrates 8 and 9. A first electrode 3 and second electrode 4 are associated with each picture element 2. The electrodes 3 and 4 are able to receive a potential difference. In Fig. 2, for each picture element 2, the first substrate has a first electrode 3 and the second substrate 9 has a second electrode 4. The

charged particles 6 are able to occupy positions near either of the electrodes 3 and 4 or intermediate to them. Each picture element 2 has an appearance determined by the position of the charged particles 6 between the electrodes 3 and 4. Electrophoretic media 5 are known per se, e.g., from U.S. patents 5,961,804, 6,120,839, and 6,130,774 and can be obtained, for instance, from E Ink Corporation.

As an example, the electrophoretic medium 5 may contain negatively charged black particles 6 in a white fluid. When the charged particles 6 are near the first electrode 3 due to a potential difference of, e.g., +15 Volts, the appearance of the picture elements 2 is white. When the charged particles 6 are near the second electrode 4 due to a potential difference of opposite polarity, e.g., -15 Volts, the appearance of the picture elements 2 is black. When the charged particles 6 are between the electrodes 3 and 4, the picture element has an intermediate appearance such as a grey level between black and white. A drive control 100 controls the potential difference of each picture element 2 to create a desired picture, e.g.. images and/or text, in a full display screen. The full display screen is made up of numerous picture elements that correspond to pixels in a display.

Fig. 3 shows diagramatically an overview of an electronic reading device. The electronic reading device 300 includes the control 100, including an addressing circuit 105. The control 100 controls the one or more display screens 310, such as electrophoretic screens, to cause desired text or images to be displayed. For example, the control 100 may provide voltage waveforms to the different pixels in the display screen 310. The addressing circuit provides information for addressing specific pixels, such as row and column, to cause the desired image or text to be displayed. As described further below, the control 100 causes successive pages to be displayed starting on different rows and/or columns. The image or text data may be stored in a memory 120. One example is the Philips Electronics small form factor optical (SFFO) disk system. The control 100 may be responsive to a user-activated software or hardware button 320 that initiates a user command such as a next page command or previous page command.

The control 100 may be part of a computer that executes any type of computer code devices, such as software, firmware, micro code or the like, to achieve the functionality described herein. Accordingly, a computer program product comprising such computer code devices may be provided in a manner apparent to those skilled in the art. Moreover, the memory 120 is a program storage device that tangibly embodies a program of instructions executable by a machine such as the control 100 or a computer to

perform a method that achieves the functionality described herein. Such a program storage device may be provided in a manner apparent to those skilled in the art.

The control 100 may have logic for periodically providing a forced reset of a display region of an electronic book, e.g., after every x pages are displayed, after every y minutes, e.g., ten minutes, when the electronic reading device is first turned on, and/or when the brightness deviation is larger than a value such as 3% reflection. For automatic resets, an acceptable frequency can be determined empirically based on the lowest frequency that results in acceptable image quality. Also, the reset can be initiated manually by the user via a function button or other interface device, e.g., when the user starts to read the electronic reading device, or when the image quality drops to an unacceptable level.

The invention may be used with any type of electronic reading device. Fig. 4 illustrates one possible example of an electronic reading device 400 having two separate display screens. Specifically, a first display region 442 is provided on a first screen 440, and a second display region 452 is provided on a second screen 450. The screens 440 and 450 may be connected by a binding 445 that allows the screens to be folded flat against each other, or opened up and laid flat on a surface. This arrangement is desirable since it closely replicates the experience of reading a conventional book.

Various user interface devices may be provided to allow the user to initiate page forward, page backward commands and the like. For example, the first region 442 may include on-screen buttons 424 that can be activated using a mouse or other pointing device, a touch activation, PDA pen, or other known technique, to navigate among the pages of the electronic reading device. In addition to page forward and page backward commands, a capability may be provided to scroll up or down in the same page. Hardware buttons 422 may be provided alternatively, or additionally, to allow the user to provide page forward and page backward commands. The second region 452 may also include on-screen buttons 414 and/or hardware buttons 412. Note that the frame 405 around the first and second display regions 442, 452 is not required as the display regions may be frameless. Other interfaces, such as a voice command interface, may be used as well. Note that the buttons 412, 414; 422, 424 are not required for both display regions. That is, a single set of page forward and page backward buttons may be provided. Or, a single button or other device, such as a rocker switch, may be actuated to provide both

page forward and page backward commands. A function button or other interface device can also be provided to allow the user to manually initiate a reset.

In other possible designs, an electronic book has a single display screen with a single display region that displays one page at a time. Or, a single display screen may be partitioned into or two or more display regions arranged, e.g., horizontally or vertically. In any case, the invention can be used with each display region to reduce the effects of color drift in the background picture.

Furthermore, when multiple display regions are used, successive pages can be displayed in any desired order. For example, in Fig. 4, a first page can be displayed on the display region 442, while a second page is displayed on the display region 452. When the user requests to view the next page, a third page may be displayed in the first display region 442 in place of the first page while the second page remains displayed in the second display region 452. Similarly, a fourth page may be displayed in the second display region 452, and so forth. In another approach, when the user requests to view the next page, both display regions are updated so that the third page is displayed in the first display region 442 in place of the first page, and the fourth page is displayed in the second display region 452 in place of the second page. When a single display region is used, a first page may be displayed, then a second page overwrites the first page, and so forth, when the user enters a next page command. The process can work in reverse for page back commands. Moreover, the process is equally applicable to languages in which text is read from right to left, such as Hebrew, as well as to languages such as Chinese in which text is read column-wise rather than row-wise.

Additionally, note that the entire page need not be displayed on the display region. A portion of the page may be displayed and a scrolling capability provided to allow the user to scroll up, down, left or right to read other portions of the page. A magnification and reduction capability may be provided to allow the user to change the size of the text or images. This may be desirable for users with reduced vision, for example.

Discussion of sub-pictures

Although the invention can be used in many different applications, it is illustrated with an application involving an electronic dictionary with multiple sub-windows or pictures. In accordance with the invention, a frame is introduced around a sub-picture when a visual characteristic of the sub-picture, e.g., color or greyscale level, is nominally the same as the background picture but in practice deviates from the background picture

due to color drift in the background picture. The color drift or degradation is caused by the fact that the image stability in a bi-stable display decreases over time. For example, Fig. 11 illustrates the brightness (L*), on the vertical axis, as a function of image holding or waiting time, in seconds, on the horizontal axis, directly after addressing to the white state. The brightness 1100 decreases almost exponentially as the waiting time increases, from a white state at a brightness of 65, to a decayed state at a brightness of 58, a decrease of 7 units. Such a curve can be experimentally determined and the values or a function such as a curve fit can be stored in a memory. The memory can then be used to estimate a current brightness value based on the time that has passed since the update.

Optionally, to further lower power consumption, the frame may be applied only when the difference is beyond a first, minimum threshold level but less than a second, maximum threshold. Thus, the frame is applied only when the visual characteristics of the background picture and sub-picture are slightly different. If the visual characteristics are very close, the degraded background will not be perceptible so there is no need for a frame. Similarly, if the visual characteristics are very far apart, the degraded background will not be perceptible, and a frame might not sufficiently break up the transition, so no frame is needed. This is true because the human eye is most sensitive to slight changes in color for adjacent regions. In some cases, such as when it is known that the background picture and sub-picture will be a certain color, e.g., white, it is sufficient to provide a frame when the visual characteristics of the sub-picture and background picture differ by more than a minimum threshold without checking to see if the difference is less than a maximum threshold.

Another example of using the maximum threshold without a frame is to have a sub-window background with a brightness contrast sufficiently high in comparing to the entire display background, e.g. the background of the sub-window may be chosen as black or dark grey when the entire display has a back ground of white or light grey.

The thresholds for the differences in the visual characteristics can be estimated, e.g., based on a predetermined reflectivity vs. unpowered image holding time curve, e.g., a bi-stability curve. Or, the difference can be measured in real time, e.g., when a photo sensor is available on each pixel. The photo-sensor approach improves the visual effect significantly. The first, minimum threshold may be set based on a minimum color difference between adjacent regions that the human eye can perceive, while the second, maximum threshold may be set based on a color difference between adjacent regions that

the human eye perceives as being distinctly or starkly contrasting. Such thresholds may be determined by experimentation, for instance.

For example, Fig. 12 illustrates a photo-sensor situated above the top electrode on the foil side of a display, and Fig. 13 illustrates a photo-sensor situated on or adjacent to the pixel electrode on the active plate of the display. Both approaches use an integral photo-sensor to monitor the grey level of the pixel by measuring the amount of scattered light. In Fig. 12, a photo-sensor 1250 is situated above the top electrode 1210 on the foil side of the display. The TFT substrate 1215, lower electrode 1212, and example pixel 1202, with electrophoretic particles 1202 are also shown. Detection of direct light is prevented by a black matrix above the photo-sensor. Light is detected after scattering from the white particles (or white fluid) in the pixel region. Some of the incident light is absorbed by the black particles in the pixel area. The amount of scattered light and the photo-sensor signal will be reduced accordingly. The disadvantage is that the photo-sensor will be situated on the opposite substrate to where the active matrix will usually be situated.

In Fig. 13, the photo-sensor 1350 is situated on or adjacent to the pixel electrode on the active plate of the display. Now the display is viewed from the active matrix side. Again, detection of direct light is prevented by a black matrix below the photo-sensor. Some of the incident light is absorbed by the black particles in the pixel area. This reduces the amount of scattered light and the photo-sensor signal will be reduced accordingly. The disadvantage is that the aperture ratio of the pixel may be reduced. More preferably, the photo-sensor could be situated at the edges of pixels or even on top of electrodes within the pixel where the light loss will be limited. In addition, the photo-sensor 1350 sees only the light absorbed in a part of the pixel – this is not always completely representative for the average situation in the entire pixel. Of course, other configurations for incorporating the photo-sensor into the display are also possible.

Fig. 5 shows a clean white sub-picture with no frame displayed over a degraded white background. Here, a display 500 of an electronic reading device includes a background region or picture 510. In the example shown, the display 500 of the electronic reading device provides a dictionary feature where a user types in words and a corresponding image appears. Moreover, an image may be displayed when only one or more letters of a word are typed in. For example, when the letter "B" is typed in, the dictionary may display an image in a sub-picture corresponding to the first word

beginning with "B'" that is stored in memory. This may be "banana", for instance. When additional letters are typed in, the next corresponding image is displayed in the sub-picture. For example, when "Be" is typed in, an image of a "bear" is displayed.

A while after the background picture 510 is displayed, the user decides to search for a specific word (e.g., Bear) and presses the letter B. The letter B is displayed on the display 500 by updating a small area or sub-picture 520 of the display 500 that fits as a rectangle around the letter B. Since some time has passed since the white background picture 510 was written, the background picture has degraded to a light grey level. In the figures, the color degradation is generally exaggerated. However, the sub-picture 520 has just been updated so it has a clean white region, at least at the periphery, around the letter "B". Thus, the white periphery of the sub-picture 520 will appear whiter than the degraded white of the background picture 510. This is clearly visible to the viewer.

A much better solution, illustrated in Fig. 6, is to display the sub-picture with a frame. The frame can be provided by the control 100 by providing an appropriate drive waveform to a region of pixels around the sub picture 520. A specific frame thickness and color can be set. In the display 600, a sub-picture 620 has a frame 622 and white area 624 that can be used for displaying additional letters that are typed in by the user. The frame 622 is shown as being black. Generally, the frame should contrast with the background picture 610 and a portion of the sub-picture, e.g., portion 624 that is adjacent to the background picture 610. Thus, when the background picture 610 and the portion 624 of the sub-picture are light, such as white, as in the present example, the frame should be dark, such as black. If the background picture 610 and the portion 624 of the sub-picture were dark, such as black, the frame should be light, such as white.

Whenever the user presses a key to type in an additional letter, the full white area inside the sub-picture 620 is updated. It is also possible to enlarge the sub-picture 620 and frame 622 to accommodate each additional letter that is typed. The transition between the degraded white background picture 610 and the clean white portion 624 inside the sub-picture 620 is not noticed since the two "whites" are not touching each other, but are separated by the frame 622. Without the frame 622, the degraded white would be noticeable when it is adjacent to the clean white.

Referring to Fig. 7, assume the dictionary application provides a first sub-picture 720 in the display 700 with the typed in letter or letters, and a second sub-picture 730 provides a corresponding image. For example, assume that when the letter "B" is typed

in, the first word that is located is "Banana". In this case, the first sub-picture 720 can be updated to display the letters "banana", not shown, while the second sub-picture 730 displays an image of a banana. Since the background picture 710 is not updated when the sub-pictures are updated, the background picture 710 will begin to degrade, e.g., to a degraded white color. This results in an undesirable transition between the background picture 710 and the sub-pictures 720 and 730 that accentuates the degradation of the background image 710.

The effect will be even worse if a second letter such as "e" is pressed that results in the display of another sub-picture that is smaller than the first image. For example, referring to Fig. 8, the display 800 includes a degraded white background image 810 and a portion 830 of a sub-picture that was previously displayed, such as the banana image of the sub-picture 730. In the first sub-picture 820, a portion 822 with the previously displayed letter "B" has a degraded white color that is similar to the degraded white color of the portion 830, but not as degraded as the background picture 810. A portion 824 with the letter "e" has a clean white color around the "e". The new sub-picture 840 also has a clean white portion around the bear image. In this case, two visible transitions are present: one between the background image 810 and the portion 830 of the banana sub-picture that was previously displayed, and one between the portion 830 of the banana sub-picture that was previously displayed and the sub-picture 840.

This problem is also avoided by displaying a frame around the first and second sub-pictures, as shown in Fig. 9. Additionally, the area of the sub-picture inside the frame is updated. This avoids the degraded appearance near the letter "B" in the sub-picture 920. Specifically, in Fig. 9, in the display 900, a first sub-picture 920 includes a frame 922 and white portion 924. A second sub-picture 930 includes a frame 932 and white portion 934. Optionally, the size of the second sub-picture 930 can be increased to encompass the remnants of the earlier sub-picture, e.g., portion 830.

Fig. 10 shows a method for determining whether to display a frame with a sub-picture. The method includes determining visual characteristics of the background picture (block 1000) and sub-picture (block 1010), or at least portions thereof, and determining a difference between the visual characteristics (block 1020). Generally, the difference indicates whether the degradation in the visual characteristic of the background picture will be noticeable if a frame is not displayed to break up the transition between the sub-picture and the background picture. For example, the degradation may be noticeable

if the difference exceeds a first, minimum threshold (block 1020) but is less than a second, maximum threshold (block 1040). This means the visual characteristics differ slightly. This generally occurs when the sub-picture and background picture are slightly different colors or greyscale levels as they appear on the display. When the adjacent sub-picture and background picture portions are starkly different, there is generally no need for a frame since there is already a sharp transition between the sub-picture and background picture. If the conditions of blocks 1030 and 1040 are met, the sub-picture is displayed with a frame (block 1050). Otherwise, the sub-picture is displayed without a frame (block 1060). In another approach, a frame may be used merely if the difference exceeds the first, minimum threshold without employing the second, maximum threshold.

The minimum threshold can be very small or even zero. The thresholds can be determined based on experiments with different viewers. As an example, assume a 4-bit (16 level) greyscale is used with white as level 1 and black as level 16. Then, assuming a minimum threshold is a difference of 2 levels, a frame is used when a background has degraded from level 1 to level 4, and a sub-picture is newly updated at level 1, since the difference is 3 levels, which exceeds the minimum threshold. The maximum threshold may be level 8, which is middle grey.

The visual characteristics of the sub-picture and background picture can be determined in different ways. The visual characteristic of the sub-picture is generally known since the sub-picture is being newly updated with a known color or greyscale level according to the data in memory that is used for updating the corresponding pixels with appropriate drive waveforms. Similarly, the visual characteristic of the background picture when it was newly updated is known. The current visual characteristic of the background image can be determined by estimation and/or measurement. It is also possible to measure the visual characteristics of the sub-picture. For the estimating approach, a pre-determined reflectivity vs. unpowered image holding time (bi-stability curve) is straightforward and depends on the material used in the display. Other factors such as temperature and brightness setting may factor into the curve. This curve indicates the degradation of a picture as a function of time. See, e.g., Fig. 11 and the associated discussion. The control 100, having an appropriate time keeping function, can then estimate the current visual characteristic, e.g., of the background image, based on its known visual characteristic when it was newly updated and the amount of time that has passed since it was newly updated. For the measurement approach, a real-time

measurement of the visual characteristic of the background image can be made when a photo-sensor is available on each pixel. This approach requires the addition of photo-sensor and the modification of pixel structure. Another possibility is to implement a function button so that the user can make his or her own choice to provide a border around a sub-picture.

Note that the sub-picture and frame can be rectangular, circular or any arbitrary shape. Moreover, any number of sub-pictures can be accommodated. Also, when a new sub-picture is displayed over a previously displayed sub-picture, the previously displayed sub-picture may be considered to form part of the background picture. Or, the new sub-picture may be expanded to encompass the remnants of the previously displayed sub-picture. Also, while the invention has been discussed in connection with a bi-stable display it is applicable was well to other display types.

While there has been shown and described what are considered to be preferred embodiments of the invention, it will, of course, be understood that various modifications and changes in form or detail could readily be made without departing from the spirit of the invention. It is therefore intended that the invention not be limited to the exact forms described and illustrated, but should be construed to cover all modifications that may fall within the scope of the appended claims. The invention may, for example, be embodied in displays other than electronic reading devices, including inter alia, bill boards or other signage, in particular signage in which part of sign is "flashed" or changed rapidly while the rest of the sign remains unchanged.